(54) **Method of extracting teeth area from teeth image and personal identification method and apparatus using the teeth image**

(57) A method of extracting a teeth area from a teeth image, and personal identification method and apparatus using characteristic elements that are extracted from the extracted teeth area are provided. The personal identification method includes constructing a database by correspondently storing teeth images from a plurality of persons and at least one teeth characteristic element of each person; (b) extracting an interline between an upper teeth portion and a lower teeth portion from an inner mouth area that is separated from a teeth image of a person to be identified, and extracting an upper teeth area and a lower teeth area on the basis of the interline; detecting one or more teeth characteristic elements from the upper and lower teeth areas; and searching the database based on the detected one or more teeth characteristic elements and determining identification pass or fail according to a similarity between the teeth image of the person to be identified and a teeth image searched from the database.

FIG. 1

```
┌─────────────────────┐
│   TEETH IMAGE       │──11
│  ACQUISITION UNIT   │
└─────────────────────┘
          │
          ▼
┌─────────────────────┐
│   TEETH IMAGE       │──13
│ PROCESSING UNIT     │
└─────────────────────┘
          ▲
          │
┌─────────────────────┐
│   TEETH IMAGE       │──15
│   DATABASE          │
└─────────────────────┘
```
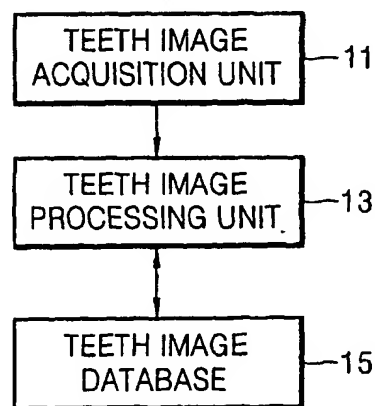
EP 1 434 164 A2

Description

[0001] The present invention relates to personal identification technology, and more particularly, to a method of extracting a teeth area from a teeth image, and a personal identification method and apparatus using characteristic elements of the extracted teeth area.

[0002] Personal identification is performed to allow access to a particular zone, such as a security area, using a person's face, fingerprint, iris, veins in the back of the hand, or voice. However, a complex algorithm is required for face recognition, and expensive equipment is required for iris recognition. In addition, it is difficult to recognize a fingerprint when the fingerprint is not clear or when a finger is stained with a foreign substance or wet because of sweat. Also, vein patterns in the back of the hand vary with circumstances. Accordingly, a personal identification method using a body part which rarely changes and the image of which can be analyzed using simple and inexpensive software and hardware is desired.

[0003] According to an aspect of the present invention, there is provided a method of extracting a teeth area from a teeth image, the method comprising: separating an inner mouth area from a teeth image of a person to be identified; extracting an interline between an upper teeth portion and a lower teeth portion from the inner mouth area; and extracting an upper teeth area and a lower teeth area on the basis of the interline.

[0004] According to another aspect of the present invention, there is provided a personal identification method using a teeth image, comprising (a) constructing a database by correspondently storing teeth images from a plurality of persons and at least one teeth characteristic element of each person; (b) extracting an interline between an upper teeth portion and a lower teeth portion from an inner mouth area that is separated from a teeth image of a person to be identified, and extracting an upper teeth area and a lower teeth area on the basis of the interline; (c) detecting one or more teeth characteristic elements from the upper and lower teeth areas; and (d) searching the database based on the detected one or more teeth characteristic elements and determining identification pass or fail according to a similarity between the teeth image of the person to be identified and a teeth image searched from the database.

[0005] According to another aspect of the invention, there is provided a complete readable recording medium on which is recorded a program for performing one of the above methods.

[0006] According to still another aspect of the present invention, there is provided a personal identification apparatus using a teeth image, comprising: a teeth image database, which correspondently stores teeth images from a plurality of persons and at least one teeth characteristic element of each person; a teeth image acquisition unit, which acquires a teeth image of a person to be identified; a teeth extractor, which performs first thresholding on the teeth image provided from the teeth image pickup unit to separate an inner mouth area, performs horizontal projection on the inner mouth area to extract an interline between an upper teeth portion and a lower teeth portion, and extracts a teeth area based on the interline; a characteristic detector, which performs vertical projection on the extracted teeth area to detect one or more teeth characteristic elements for distinguishing an individual person's teeth from others; a search section, which searches the teeth image database using at least one among the teeth characteristic elements detected by the characteristic detector; and an identification section, which determines identification pass or fail according to a similarity between the teeth image of the person to be identified and a teeth image searched from the search section.

[0007] The present invention provides a method of extracting a teeth area from a teeth image of a person to be identified.

[0008] The present invention also provides a personal identification method and apparatus using a teeth area which rarely changes and the image of which is can be analyzed in a simple way.

[0009] The above and other features and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a block diagram of a personal identification apparatus using a teeth image according to a preferred embodiment of the present invention;

FIG. 2 is a detailed block diagram of a teeth image processing unit shown in FIG. 1;

FIG. 3 is a flowchart showing operations performed by a teeth extractor shown in FIG. 2;

FIGS. 4A through 4F are diagrams showing the results of the respective operations shown in FIG. 3;

FIGS. 5A and 5B are diagrams for explaining the operation of a characteristic detector shown in FIG. 2;

FIGS. 6A and 6B are examples of teeth images used for segmenting a teeth area and extracting characteristic elements according to an embodiment of the present invention;

FIGS. 7A and 7B are examples of upper and lower teeth areas extracted from the teeth areas, respectively, shown in FIGS. 6A and 6B;

FIGS. 8A and 8B are graphs showing the results of performing vertical projection on the upper teeth areas shown in the FIGS. 7A and 7B, respectively; and

FIGS. 9A and 9B are graphs showing the results of performing vertical projection on the lower teeth areas shown in the FIGS. 7A and 7B, respectively.

[0010]   Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the attached drawings.

[0011]   FIG. 1 is a block diagram of a personal identification apparatus using a teeth image according to a preferred embodiment of the present invention. The personal identification apparatus includes a teeth image acquisition unit 11, a teeth image processing unit 13, and a teeth image database 15.

[0012]   The teeth image acquisition unit 11 is usually composed of a typical digital camera, such as an exclusive camera for photographing teeth, a camera attached to a personal computer, or a camera attached to a mobile communication terminal. When personal identification is required, the teeth image acquisition unit 11 photographs the entire front teeth portion of a person to be identified to acquire a teeth image and provides the teeth image to the teeth image processing unit 13. It is preferable that the teeth are photographed in a state in which the upper teeth are separated from the lower teeth by a predetermined distance in order to facilitate the separate extraction of an upper teeth area and a lower teeth area.

[0013]   The teeth image processing unit 13 extracts a teeth area from the teeth image provided from the teeth image acquisition unit 11 by performing a thresholding process, a projection process, and an area growth process; detects characteristic elements of the teeth; and searches the teeth image database 15 based on the characteristic elements. Here, various methods can be used to identify the person. For example, a similarity in each characteristic element between a currently input teeth image and a teeth image from the teeth image database 15 is calculated. Identification succeeds when the teeth image database 15 includes a teeth image having the similarity or an average of the similarities in all of the characteristic elements, which exceeds a predetermined reference value, while identification fails when the teeth image database 15 does not include such a teeth image. The reference value may be optimally set through experiments or simulations.

[0014]   The teeth image database 15 is constructed by acquiring teeth images from many persons and correspondently storing them along with personal information including a personal identifier, teeth information, and the characteristic elements of the teeth. Here, as well as a front view of the teeth, various views thereof can be stored. The characteristic elements of teeth include the shapes and colors of the teeth, an area ratio between teeth, a width ratio between teeth, and a teeth arrangement.

[0015]   The personal identification apparatus of the present invention can be implemented in personal mobile communication equipment, such as a cellular phone or a personal digital assistant (PDA), so that it can be used for personal identification when security is required, for example, when the personal mobile communication equipment is lost or when electronic payment is performed through the personal mobile communication equipment. In this situation, the teeth image database 15 stores the teeth image of the owner of the mobile communication equipment along with the owner's personal information, teeth information, and characteristic elements of the teeth.

[0016]   FIG. 2 is a detailed block diagram of the teeth image processing unit 13 shown in FIG. 1. The teeth image processing unit 13 includes a teeth extractor 21, a characteristic detector 23, a search section 25, and an identification section 27.

[0017]   The teeth extractor 21 extracts a teeth area from a teeth image provided by the teeth image acquisition unit 11. The teeth extractor 21 separates the inner area of a mouth from the teeth image, extracts an interface between an upper teeth portion and a lower teeth portion, and extracts a teeth area based on the extracted interface between the upper and lower teeth portions.

[0018]   The characteristic detector 23 extracts characteristic elements for identifying an individual's teeth from the teeth area extracted by the teeth extractor 21. Extractable characteristic elements are the shapes and colors of teeth, an area ratio between teeth, a width ratio between teeth, and a teeth arrangement.

[0019]   Teeth shape and arrangement information can be obtained from an image pattern of the extracted teeth area. Information on the area ratio and the width ratio between the teeth can be obtained by performing vertical projection on the teeth area. Teeth color information can be obtained by performing a histogram process on the brightness of the teeth area.

[0020]   The search section 25 searches the teeth image database 15 using the teeth characteristic elements detected by the characteristic detector 23. Here, all of the teeth characteristic elements are not simultaneously used, but search using a teeth characteristic element, such as a width ratio between teeth, which requires a short processing time in a projection image, is performed first to extract candidate teeth images having similarities exceeding a reference value. Thereafter, the search section 25 searches the candidate teeth images using the other teeth characteristic elements. The reference value may be optimally set through experiments or simulations.

[0021]   The identification section 27 determines that the identification has succeeded when a teeth image that has a similarity with respect to each teeth characteristic element or an average of similarities with respect to all of the teeth characteristic elements, which exceeds a reference value, is found as the result of the search performed by the search section 25. When such a teeth image is not found, the identification section 27 determines that the identification has failed. The identification section 27 outputs a signal corresponding to the result of the determination.

[0022]   FIG. 3 is a flowchart showing operations performed by the teeth extractor 21 shown in FIG. 2. The teeth

extractor 21 performs separation of the inner area of a mouth (31), extraction of an interface between an upper teeth portion and a lower teeth portion (35), and detection of a teeth area (36). The operations shown in FIG. 3 will be described with reference to FIGS. 4A through 4F.

[0023]   Step 31 is provided in order to separate the inner area of a mouth from a teeth image and includes thresholding (32), labeling (33), and selection of a maximum area (34).

[0024]   Thresholding is performed on a teeth image (FIG. 4A) using Formula (1) in step 32.

$$g(x) = 1, \quad f(x) \leq T$$
$$g(x) = 0, \quad f(x) > T$$
...(1)

[0025]   Here, $f(x)$ is a pixel value at a pixel position x in the teeth image and $0 \leq f(x) \leq 255$, and $g(x)$ is a pixel value indicating the inner area of a mouth and may have a value of 0 or 1. T is a threshold value, for example, 70, and can be obtained through experiments. In the meantime, at least one among the red (R), green (G), and blue (B) color values of each pixel or $I(x)$ corresponding to a brightness in a Hue Saturation Intensity (HSI) color coordinate system can be used as $f(x)$. In order to obtain $I(x)$ from the R, G, and B color values, an RGB/HSI color coordinate system conversion formula shown in Formula (2) is used. Here, the RGB and HSI color coordinate systems are used, but other various color coordinate systems such as CMY, YIQ, and HSV color coordinate systems can also be used.

$$I = F \frac{R + G + B}{3}$$

$$H = \frac{F}{2\pi} \cos^{-1} \left\{ \frac{\frac{1}{2}[(R-G) + (R-B)]}{[(R-G)^2 + (R-B)(G-B)]^{1/2}} \right\}$$
...(2)

$$S = F \left\{ 1 - \frac{3}{R + G + B} \min(R, G, B) \right\}$$

[0026]   Here, $0 \leq R, G, B \leq 1$, and F is a constant that is typically equal to 255. As a result of performing thresholding according to formula (1) on the teeth image (FIG. 4A) provided by the teeth image acquisition unit 11, first areas set to 0 and second areas set to 1 are defined.

[0027]   In step 33, labeling is performed on contour portions of the second areas smaller than the first areas so that areas 41 and 43, in which the value of $g(x)$ for each pixel is 1, are separated, as shown in FIG. 4B.

[0028]   In step 34, the maximum area 41 between the areas 41 and 43 separated as the result of the labeling is selected so that the area 41 is separated as an inner mouth area from the teeth image (FIG. 4A), as shown in FIG. 4C.

[0029]   In step 35, a graph shown in FIG. 4D is obtained by performing horizontal projection on the inner mouth area 41 separated in step 34 in order to extract an interface between an upper teeth portion and a lower teeth portion from the teeth image. In FIG. 4D, an X-axis indicates a vertical distance "d" from above to downward in the teeth image, and a Y-axis indicates a thresholded pixel accumulation value P(d) at each position corresponding to the vertical distance "d". As the result of performing the horizontal projection, a position "k" at which the pixel accumulation value P (d) is maximum is selected as a vertical distance corresponding to the interface between the upper teeth portion and the lower teeth portion. Here, it is preferable to make a teeth arrangement horizontal by rotating the teeth image such that a pixel accumulation value P(d) at the position "k" corresponding to the interface between the upper teeth portion and the lower teeth portion becomes a maximum peak. An interline 45 is set, as shown in FIG. 4E, based on the vertical distance "k" corresponding to the interface between the upper teeth portion and the lower teeth portion.

[0030]   In step 36, an upper teeth area 47 and a lower teeth area 49 are extracted, as shown in FIG. 4F, by performing area growth on the basis of the interline 45 or by setting a predetermined upper area and a predetermined lower area to have a rectangular shape on the basis of the interline 45 and then performing thresholding on the predetermined upper and lower areas. When using an area growth method, seed points are set at predetermined positions, respec-

tively, above and below the interline 45, referring to $H(x)$ corresponding to a hue in the *HSI* color coordinate system, and an area having a similar color to each seed point is extended around the seed point. It is preferable to exclude black and red from the color of the seed point.

[0031] FIGS. 5A and 5B are diagrams for explaining the operation of the characteristic detector 23 shown in FIG. 2. A graph shown in FIG. 5B is obtained as the result of performing vertical projection on an upper teeth area 51 shown in FIG. 5A. In FIG. 5B, an X-axis indicates a horizontal distance "d" from left to right in a teeth image, and a Y-axis indicates a thresholded pixel accumulation value $P(d)$ at each position corresponding to the horizontal distance "d". As the result of performing the vertical projection, four peaks having large pixel accumulation values $P(d)$ are generated, and portions that are formed based on the four peaks, respectively, correspond to four teeth t1 through t4, respectively, that exist in the upper teeth area 51. By performing the vertical projection, the number of teeth, a tooth area (e.g., a_{i-1} or a_{i+2}), an area ratio (e.g., a_{i-1}/a_{i+2}), a tooth width (e.g., w_i or w_{i+1}), and a width ratio (e.g., w_i/w_{i+1}) can be calculated.

[0032] A personal identification method according to an embodiment of the present invention will be simply described with reference to examples of different persons' teeth images (referred to as an object #1 and an object #2, respectively) shown in FIGS. 6A and 6B, respectively.

[0033] FIGS. 7A and 7B show upper teeth areas 71 and 75 and lower teeth areas 73 and 77, respectively, which are extracted by performing thresholding, labeling, selection of a maximum area, vertical projection, and area growth on the teeth images shown in FIGS. 6A and 6B.

[0034] FIGS. 8A and 8B are graphs showing the results of performing vertical projection on the upper teeth areas 71 and 75 shown in the FIGS. 7A and 7B, respectively. FIGS. 9A and 9B are graphs showing the results of performing vertical projection on the lower teeth areas 73 and 77 shown in the FIGS. 7A and 7B, respectively. Referring to FIGS. 8A and 8B, teeth t1 through t4 exist in the upper teeth area 71 of the teeth image shown in FIG. 6A, and teeth t5 through t10 exist in the upper teeth area 75 of the teeth image shown in FIG. 6B. Referring to FIGS. 9A and 9B, teeth b1 through b6 exist in the lower teeth area 73 of the teeth image shown in FIG. 6A, and teeth b7 through b12 exist in the lower teeth area 77 of the teeth image shown in FIG. 6B.

[0035] In this personal identification technique, the number of teeth, a central position of each tooth, and a width of each tooth, which are obtained through vertical projection, are used as teeth characteristic elements. These teeth characteristic elements can be calculated from FIGS. 8A through 9B, as shown in the following table.

Object		Number of teeth	Central position of each tooth	Width of each tooth
Object #1	Upper teeth	4	116, 159, 200, 236	37, 42, 39, 24
	Lower teeth	6	113, 144, 171, 198, 233, 259	28, 20, 19, 20, 21, 31
Object #2	Upper teeth	6	45, 94, 156, 237, 289, 322	29, 26, 68, 63, 28, 17
	Lower teeth	7	65, 82, 155, 197, 250, 272, 287	29, 38, 50, 28, 48, 7, 29

[0036] Referring to the above table, it can be concluded that people have greatly different teeth characteristic elements from one another so that personal identification can be performed using the teeth characteristic elements.

[0037] The present invention can be realized as program codes which are recorded on a computer readable recording medium and can be read by a computer. For example, a method of extracting a teeth area from a teeth image can be implemented by recording on a computer readable recording medium a first program for performing thresholding on a teeth image of a person to be identified using a predetermined threshold value, and selecting a maximum area from areas that are defined by performing labeling on thresholded pixels, thereby separating an inner mouth area from the teeth image; a second program for performing horizontal projection on the inner mouth area and setting an interline between an upper teeth portion and a lower teeth portion based on a position, at which a pixel accumulation value is maximum as the result of the horizontal projection; and a third program for extracting upper and lower teeth areas on the basis of the interline. Further, a personal identification method using a teeth image can be implemented by recording on a computer readable recording medium a first program for constructing a database by correspondently storing teeth images from a plurality of persons and at least one teeth characteristic element of each person; a second program for extracting an interline between an upper teeth portion and a lower teeth portion from an inner mouth area that is separated from a teeth image of a person to be identified, and extracting an upper teeth area and a lower teeth area on the basis of the interline; a third program for detecting one or more teeth characteristic elements from the upper and lower teeth areas; and a fourth program for searching the database based on the detected one or more teeth characteristic elements and determining identification pass or fail according to a similarity between the teeth image of the person to be identified and a teeth image searched from the database.

[0038] The computer readable recording medium may be any type of medium on which data which can be read by a computer system can be recorded, for example, a ROM, a RAM, a CD-ROM, a magnetic tape, a floppy disc, or an

optical data storage device. The present invention can also be realized as carrier waves (for example, transmitted through Internet). Alternatively, computer readable recording media are distributed among computer systems connected through a network so that the present invention can be realized as a code which is stored in the recording media and can be read and executed in the computers. Functional programs, codes, or code segments for implementing the present invention can be easily inferred by programmers skilled in the field of this invention.

[0039] As described above, according to the present invention, in a situation requiring personal identification, for example, when a person enters a particular area, deposits or withdraws money at an automatic teller machine (ATM), or uses an electronic payment service through mobile communication equipment, personal identification is performed using a teeth image, which is simply recognizable and from which characteristic elements are simply extracted, thereby increasing the speed of personal identification and decreasing the cost for implementation.

[0040] In addition, a personal identification method and apparatus according to the present invention can be combined with conventional identification technology using a password in a simple stage or can be easily combined with conventional identification technology using a face, a fingerprint, an iris, veins in the back of the hand, or a voice when a high degree of personal identification is required.

[0041] In the drawings and specification, preferred embodiments of the invention have been described using specific terms but it is to be understood that such terms have been used only in a descriptive sense and such descriptive terms should not be construed as placing any limitation on the scope of the invention. Accordingly, it will be apparent to those of ordinary skill in the art that various changes can be made to the embodiments without departing from the scope of the invention, as defined by the appended claims.

Claims

1. A method of extracting an upper teeth area and a lower teeth area from a teeth image comprising the upper teeth area, the lower teeth area and an inner mouth area, the method comprising:

    separating the inner mouth area from a teeth area of the teeth image of a person to be identified;
    defining an interline between an upper teeth portion and a lower teeth portion of the teeth area on the basis of the inner mouth area; and
    extracting an upper teeth area and a lower teeth area on the basis of the interline.

2. The method of claim 1, wherein separating the inner mouth area comprises:

    defining first areas and second areas by performing thresholding on each pixel of the teeth image using a predetermined threshold value;
    labeling contour portions of the second areas smaller than the first areas; and
    selecting and determining a maximum area among the labeled second areas as the inner mouth area.

3. The method of claim 2, wherein defining the first and second areas comprises performing thresholding using at least one among red (R), green (G), and blue (B) color values of each pixel in the teeth image.

4. The method of claim 2, wherein defining the first and second areas comprises converting RGB color values of each pixel in the teeth image into Hue Saturation Intensity (HSI) color values and performing the thresholding using the converted I color value.

5. The method of any one of the preceding claims, wherein defining the interline comprises:

    performing horizontal projection on the inner mouth area; and
    setting the interline based on a position at which a pixel accumulation value is maximum as the result of the horizontal projection.

6. The method of any one of the preceding claims, wherein extracting the upper and lower teeth areas comprises extending an area having a similar color to each of seed points, which are respectively set at predetermined positions above and below the interline, from the seed point.

7. The method of any one of claims 1 to 5, wherein extracting the upper and lower teeth areas comprises:

    setting a predetermined upper area and a predetermined lower area to have a rectangular shape on the basis

of the interline; and
performing thresholding on the predetermined upper and lower areas using a predetermined threshold value.

8. A personal identification method using a teeth image, comprising:

(a) constructing a database by correspondently storing teeth images from a plurality of persons and at least one teeth characteristic element of each person;
(b) the method of any one of claims 1 to 7;
(c) detecting one or more teeth characteristic elements from the upper and lower teeth areas; and
(d) searching the database based on the detected one or more teeth characteristic elements and determining identification pass or fail according to a similarity between the teeth image of the person to be identified and a teeth image searched from the database.

9. The personal identification method of claim 8, wherein step (c) comprises:

performing vertical projection on each of the extracted upper and lower teeth areas; and
obtaining information on the number of teeth in the upper and lower teeth areas, an area ratio between teeth, and a width ratio between teeth from the result of the vertical projection.

10. The personal identification method of claim 8, wherein step (c) comprises obtaining information on shapes of teeth and teeth arrangement from an image pattern of the extracted upper and lower teeth areas.

11. The personal identification method of claim 8, wherein step (c) comprises obtaining information on colors of teeth by obtaining a brightness histogram of the extracted upper and lower teeth areas.

12. The personal identification method of any one of claims 8 to 11, wherein step (d) comprises:

searching the database using one of the detected teeth characteristic elements to extract candidate teeth images; and
searching the candidate teeth images using at least one teeth characteristic element among the other teeth characteristic elements than the one used to extract the candidate teeth images.

13. A computer readable recording medium on which is recorded a program for performing the method of any one of the preceding claims.

14. The computer readable recording medium of claim 13, wherein the program comprises a separate program for each method step.

15. A personal identification apparatus using a teeth image, comprising:

a teeth image database, which correspondently stores teeth images from a plurality of persons and at least one teeth characteristic element of each person;
a teeth image acquisition unit, which acquires a teeth image of a person to be identified;
a teeth area extractor, which performs first thresholding on the teeth image provided from the teeth image acquisition unit to separate an inner mouth area from a teeth area of the teeth image, performs horizontal projection on the inner mouth area to define an interline between an upper teeth portion and a lower teeth portion, and extracts an upper teeth area and a lower teeth area based on the interline;
a characteristic detector, which performs vertical projection on the extracted upper and lower teeth areas to detect one or more teeth characteristic elements for distinguishing an individual person's teeth from others;
a search section, which searches the teeth image database using at least one among the teeth characteristic elements detected by the characteristic detector; and
an identification section, which determines identification pass or fail according to a similarity between the teeth image of the person to be identified and a teeth image searched from the search section.

16. The personal identification apparatus of claim 15, wherein the teeth area extractor extends an area having a similar color to each of seed points, which are respectively set at predetermined positions above and below the interline, from the seed point in order to extract the upper and lower teeth areas.

17. The personal identification apparatus of claim 15, wherein the teeth area extractor sets a predetermined upper area and a predetermined lower area to have a rectangular shape on the basis of the interline and performs second thresholding on the predetermined upper and lower areas, in order to extract the upper and lower teeth areas.

18. The personal identification apparatus of any one of claims 15 to 17, wherein the characteristic detector obtains a brightness histogram of the extracted upper and lower teeth areas in addition to the vertical projection on the teeth area.

19. The personal identification apparatus of any one of claims 15 to 18, wherein the search section searches the teeth image database using one of the detected teeth characteristic elements to extract candidate teeth images, and searches the candidate teeth images using at least one teeth characteristic element among the other teeth characteristic elements than the one used to extract the candidate teeth images.
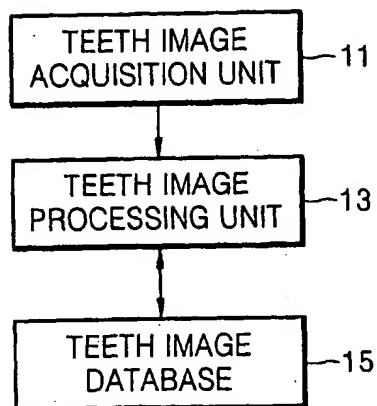
FIG. 1

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┌─────────────────────┐
│    TEETH IMAGE      │
│  ACQUISITION UNIT   │── 11
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│    TEETH IMAGE      │
│  PROCESSING UNIT    │── 13
└─────────────────────┘
           │
           ▼
┌─────────────────────┐
│    TEETH IMAGE      │
│     DATABASE        │── 15
└─────────────────────┘
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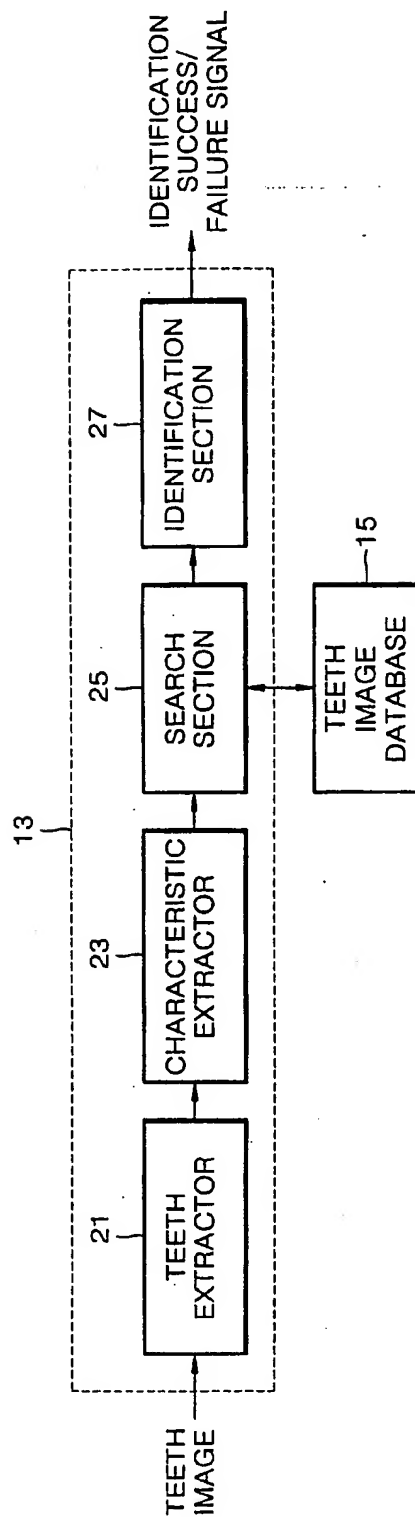
FIG. 2

TEETH
IMAGE →

21 TEETH EXTRACTOR

23 CHARACTERISTIC EXTRACTOR

25 SEARCH SECTION

27 IDENTIFICATION SECTION

→ IDENTIFICATION SUCCESS/ FAILURE SIGNAL

13

15 TEETH IMAGE DATABASE

FIG. 3

```
          ┌─────────────┐
          │    START    │
          └─────────────┘
                 │                            31
      ┌ ─ ─ ─ ─ ─│─ ─ ─ ─ ─ ─ ─ ─ ┐
      │          ▼                 │
      │  ┌───────────────────┐     │
      │  │   THRESHOLDING    │─────┼──32
      │  └───────────────────┘     │
      │          │                 │
      │          ▼                 │
      │  ┌───────────────────┐     │
      │  │     LABELING      │─────┼──33
      │  └───────────────────┘     │
      │          │                 │
      │          ▼                 │
      │  ┌───────────────────┐     │
      │  │   SELECTION OF    │─────┼──34
      │  │   MAXIMUM AREA    │     │
      │  └───────────────────┘     │
      └ ─ ─ ─ ─ ─│─ ─ ─ ─ ─ ─ ─ ─ ┘
                 ▼
      ┌───────────────────────┐
      │ EXTRACTION OF INTERFACE│
      │  BETWEEN UPPER TEETH   │──35
      │    PORTION AND LOWER   │
      │     TEETH PORTION      │
      └───────────────────────┘
                 │
                 ▼
      ┌───────────────────────┐
      │     DETECTION OF       │──36
      │      TEETH AREA        │
      └───────────────────────┘
                 │
                 ▼
          ┌─────────────┐
          │     END     │
          └─────────────┘
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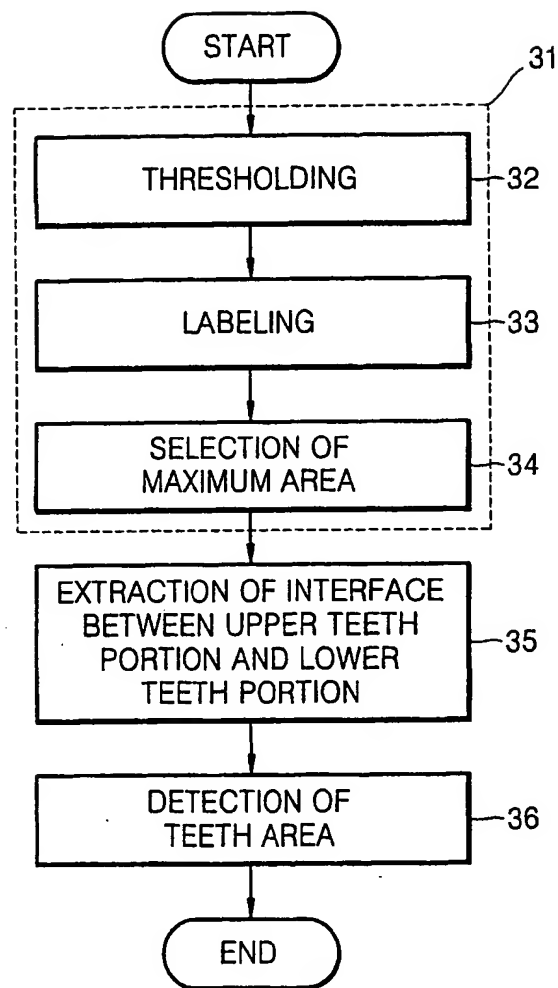
FIG. 4A

FIG. 4B

FIG. 4C

FIG. 4D

FIG. 4E

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FIG. 4F

47

49
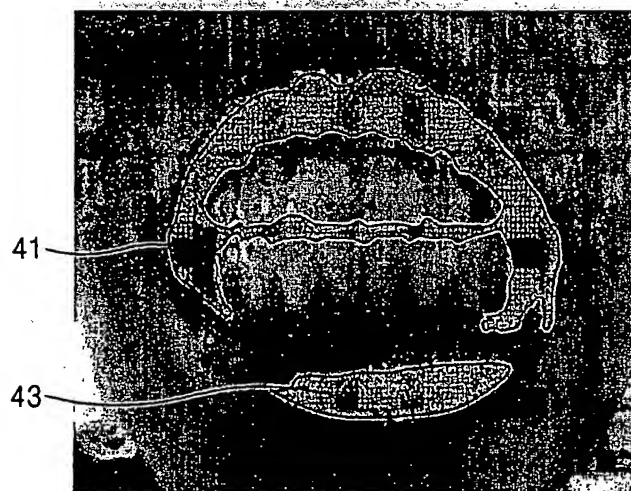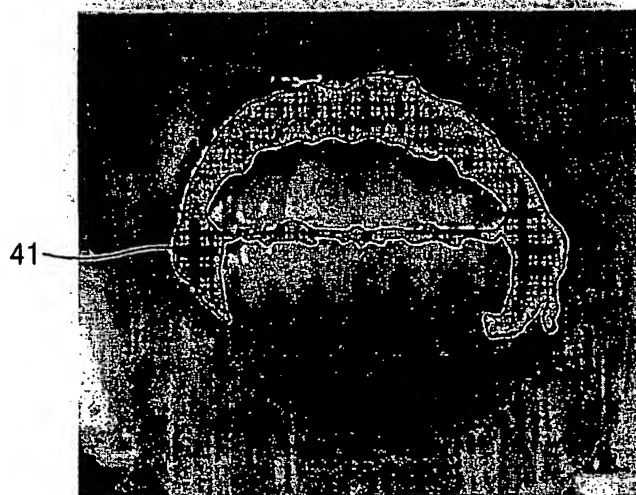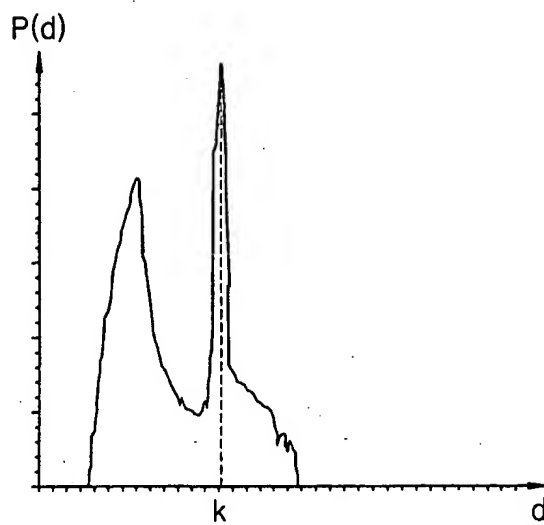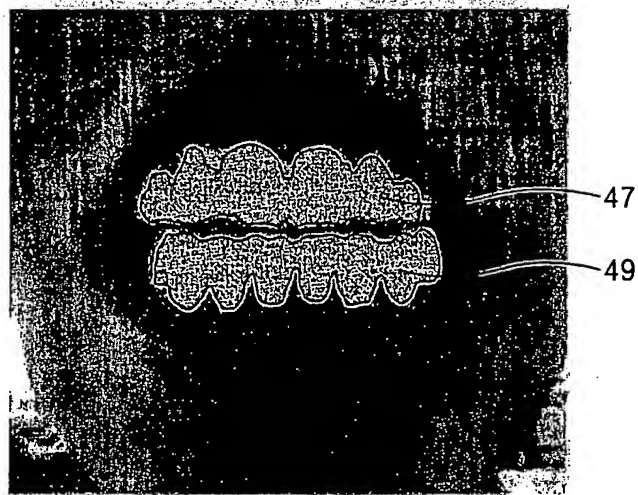
FIG. 5A
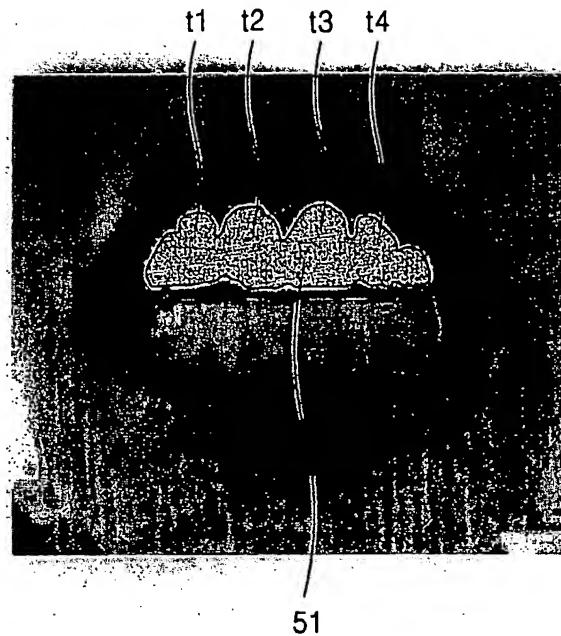
FIG. 5B
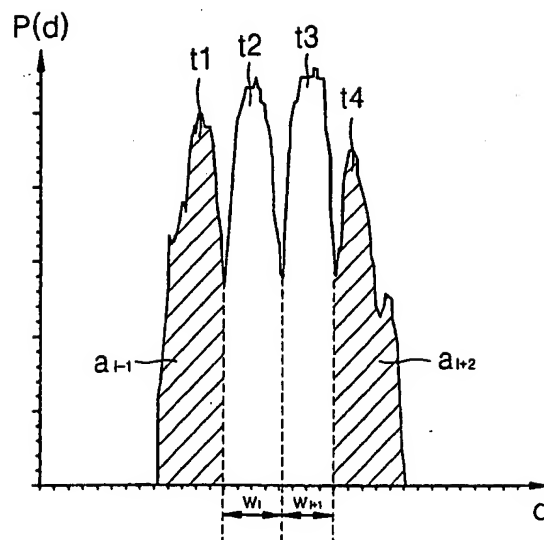
FIG. 6A
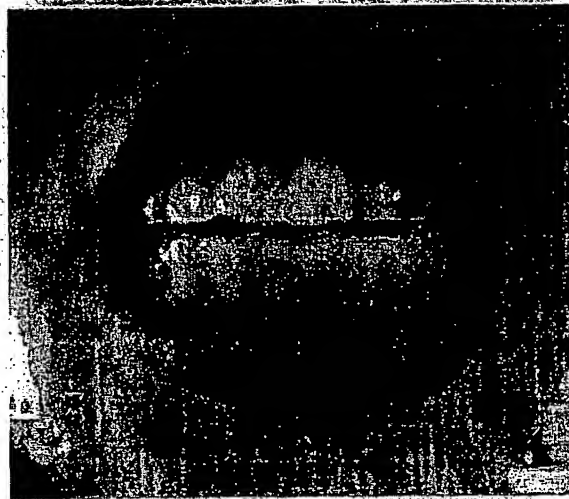
FIG. 6B
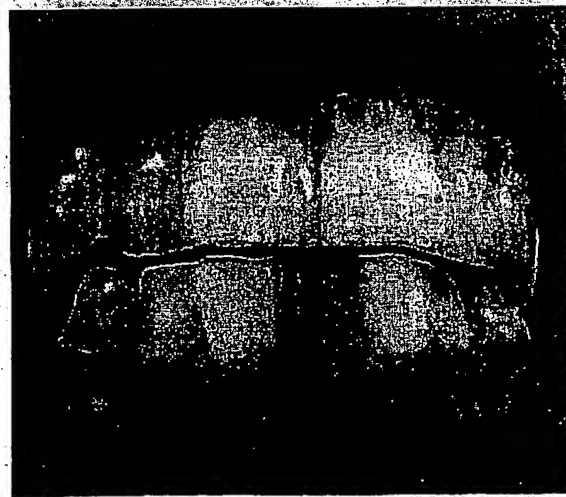
FIG. 7A
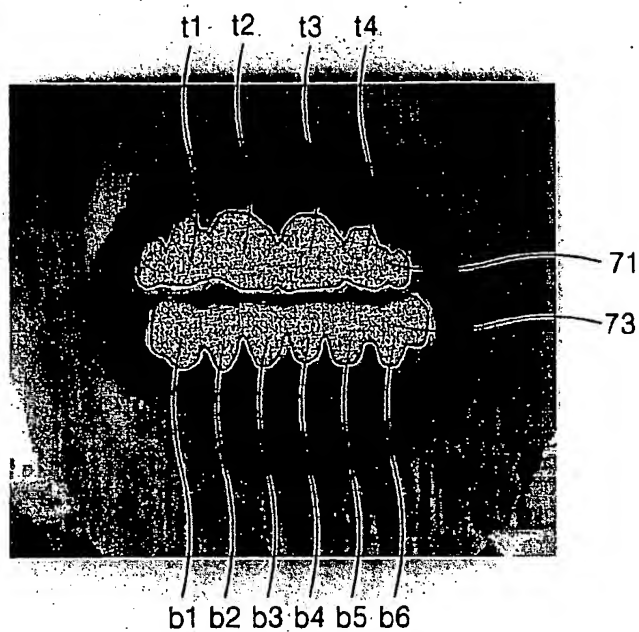
FIG. 7B

FIG. 8A

FIG. 8B

FIG. 9A

FIG. 9B